Armed Forces College of Medicine

AFCM

Synapse physiology

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INTENDED LEARNING OBJECTIVES (ILO)

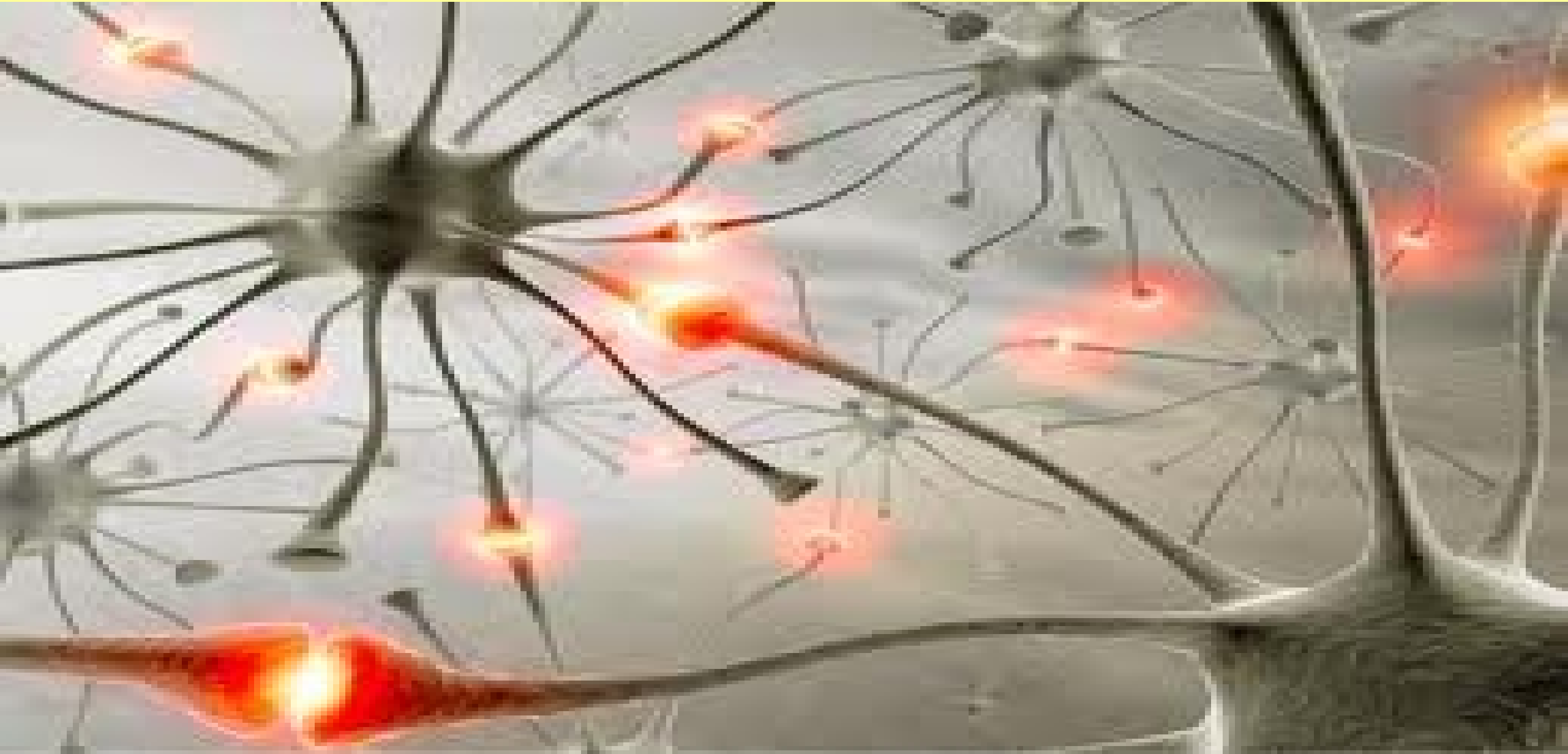
By the end of this lecture the student will be able to:

1. Define synapse and list their types
2. Explain the types of synaptic transmission.
3. Recognize the mechanisms of post-synaptic potentials.
4. Compare between types of post-synaptic potentials
5. Recognize types of summation of postsynaptic potentials
6. Differentiate between synaptic inhibition types
7. Describe the properties of synaptic transmission.

Lecture Plan

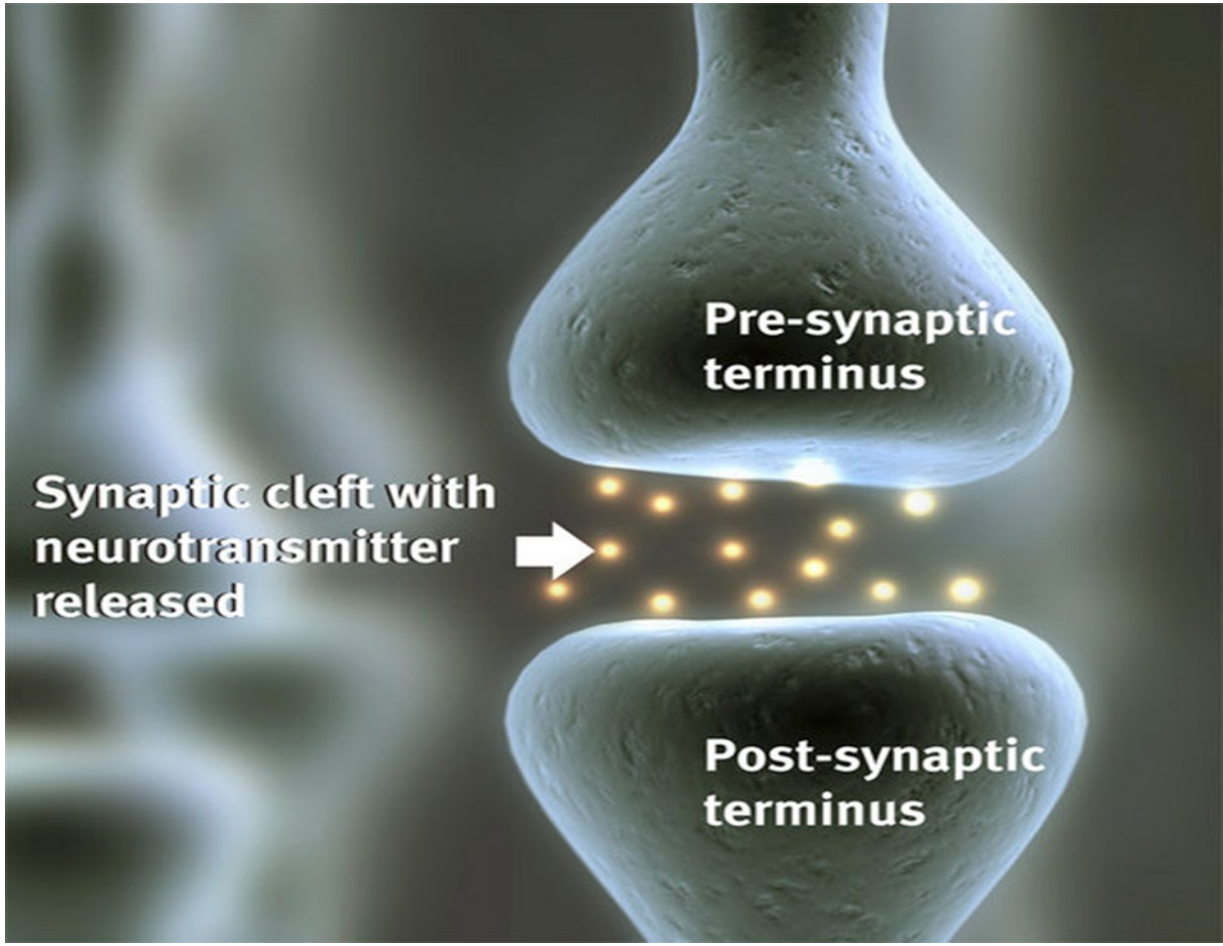
1. Define synapse and its types(10 min)
2. Synaptic summation(10 min)
3. Synaptic properties (20 min)
4. Summary (5 min)
5. Lecture Quiz (5 min)

- **The brain neurons form complex networks of neurons linked by synapses.**

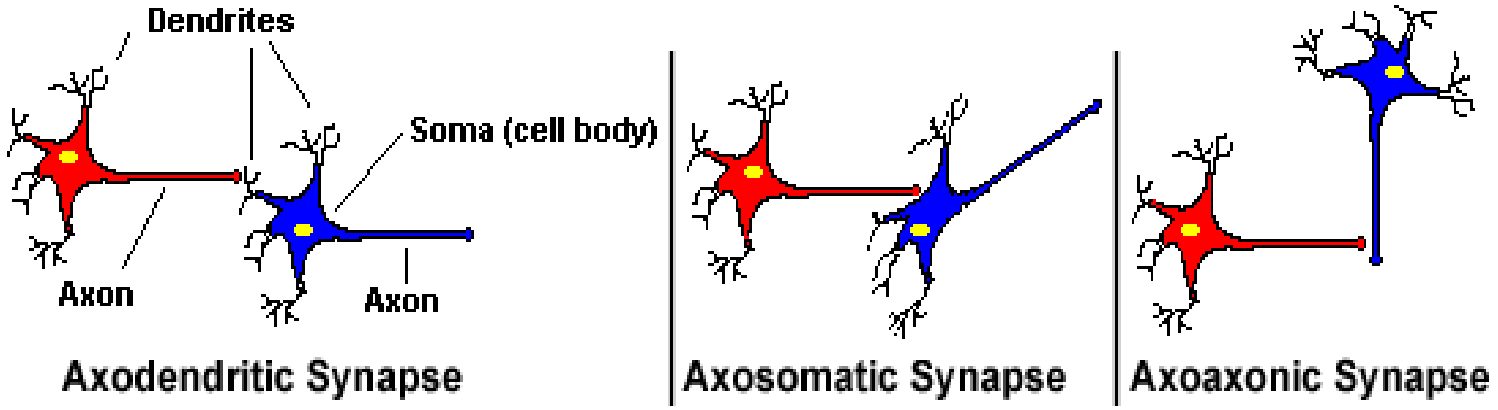


Q1:Define synapse

- It is the junction across which a nerve impulse passes from one nerve cell to another.
- The neuron before the synapse is called pre-synaptic neuron
- The neuron after the synapse is called postsynaptic neuron



- The axon of the pre-synaptic neuron terminates on the dendrites, soma or axon of the postsynaptic cell.



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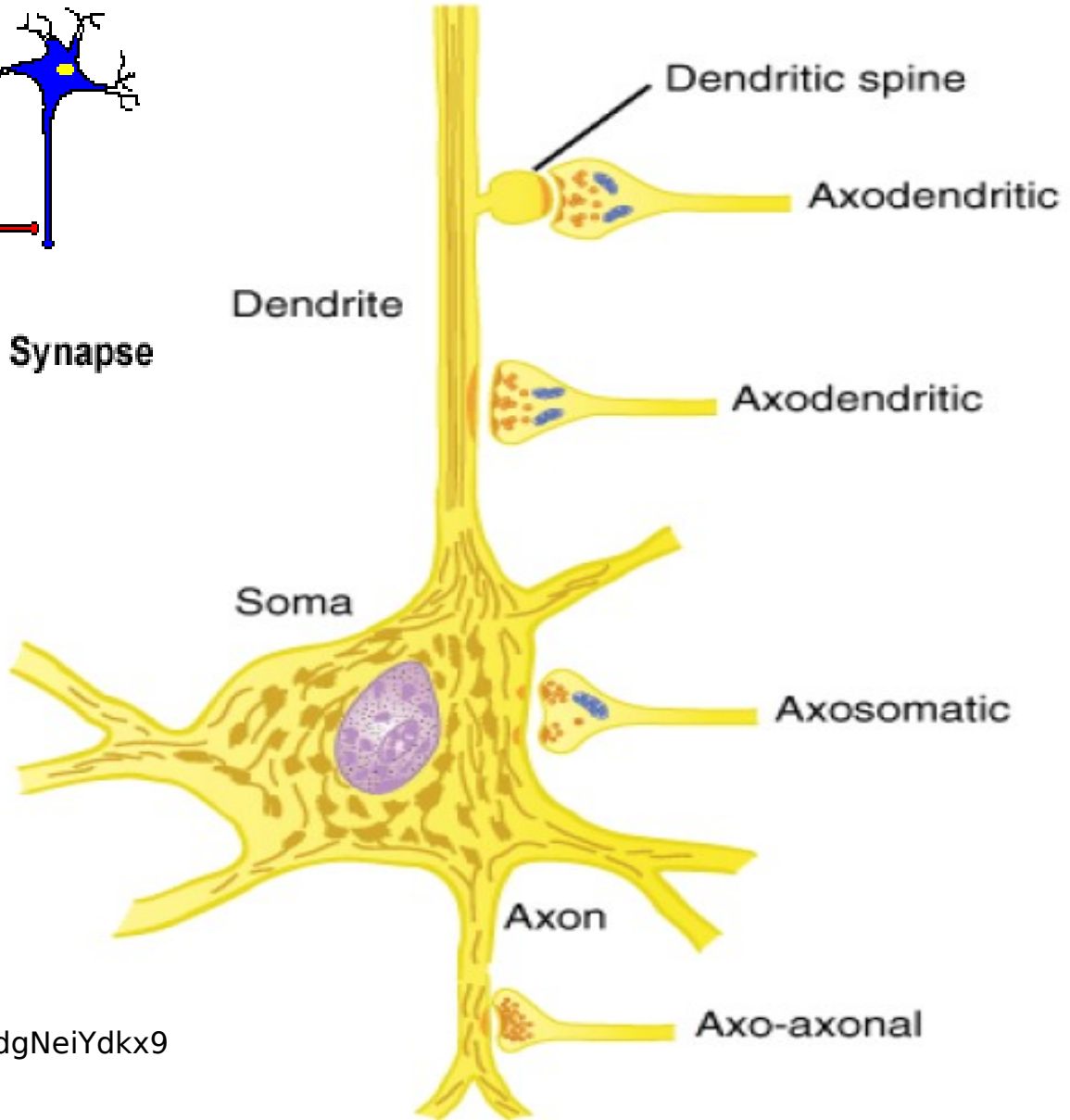
More excitable, more sodium channels



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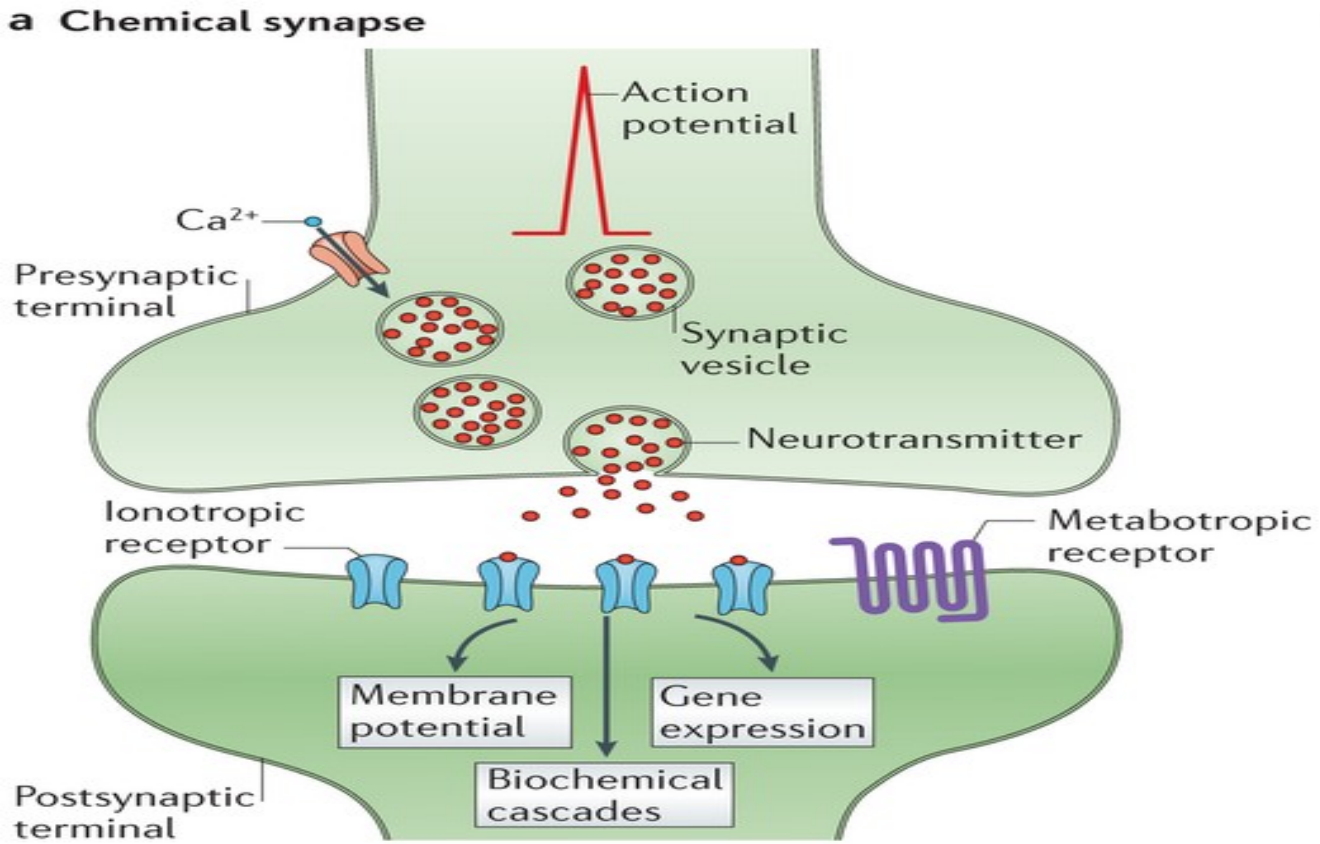
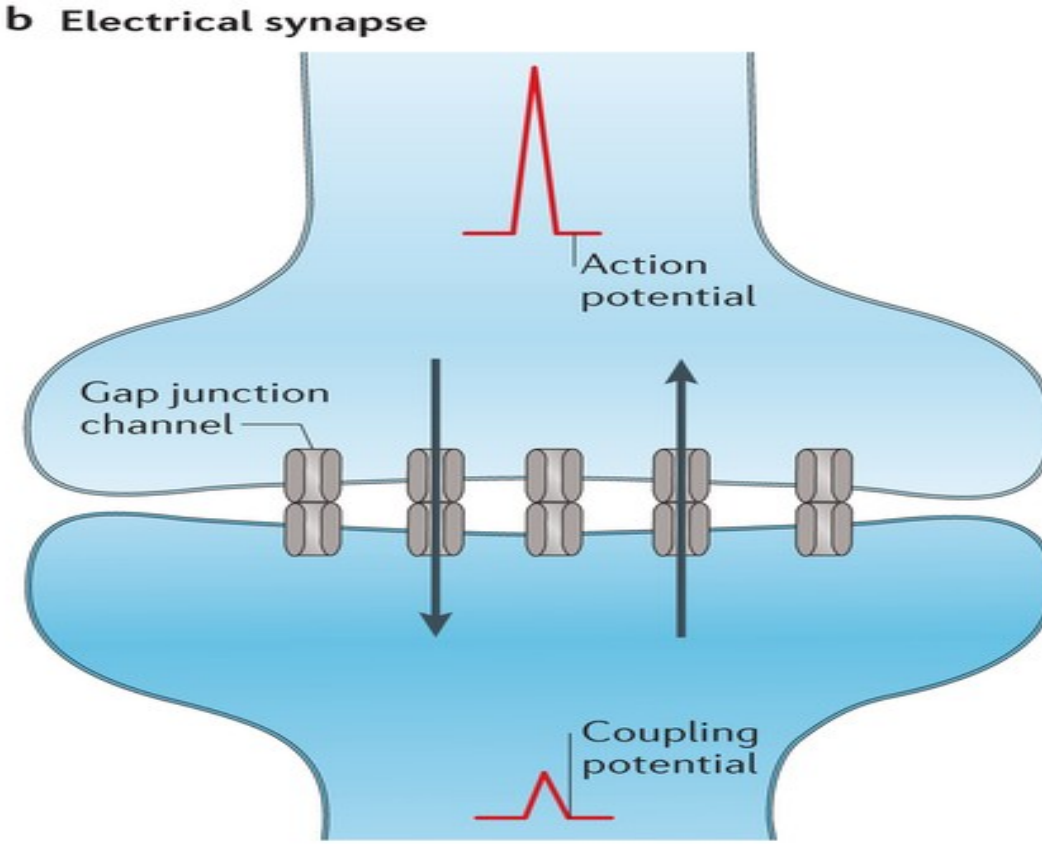
Q2-What are the physiological types of synapses





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- Most common in CNS
- Depend on neurotransmitter release

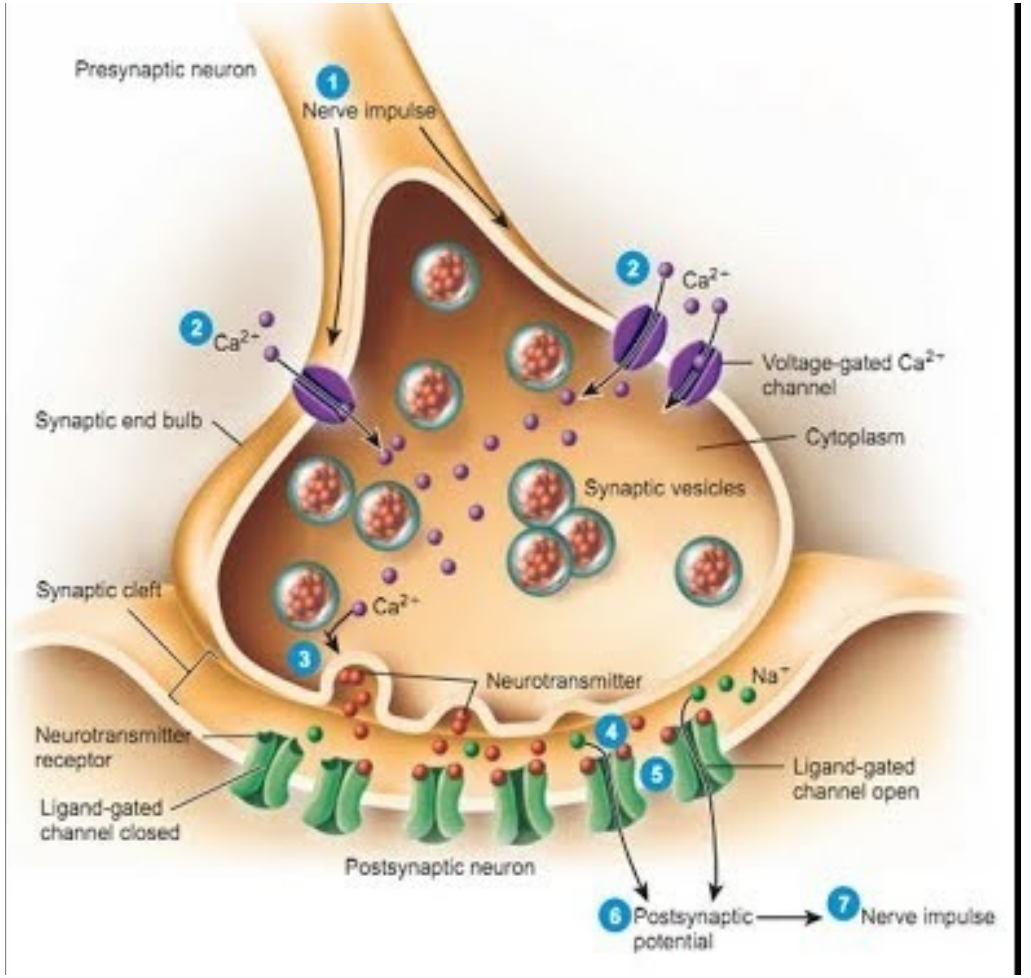
- Depend on gap Junctions

Synapse types

- Histological :Axo-dendritic, axo-somatic and axoaxonic
- Physiological: electrical (rare, bidirectional) and chemical (common unidirectional)

Q3:Mechanism of impulse transmission in chemical synapses?

- Action potential reaches the pre-synaptic terminal
- This opens voltage gated calcium channels in the synaptic knobs
- Ca++ enters the pre-synaptic endings and triggers fusion of the membrane of the vesicles to the terminal knobs
- This leads to rupture of the vesicles and release of the chemical transmitter {exocytosis}.



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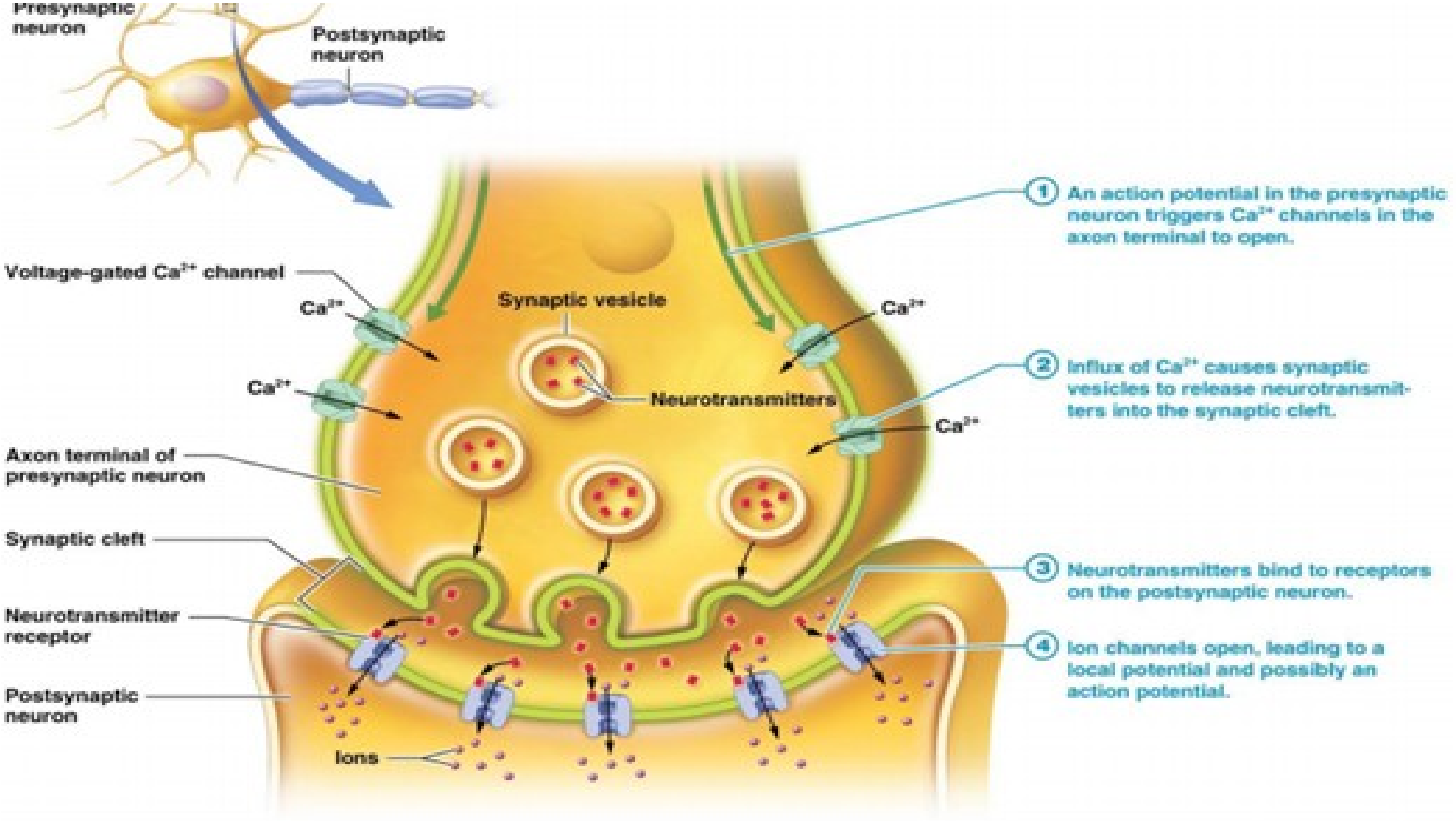

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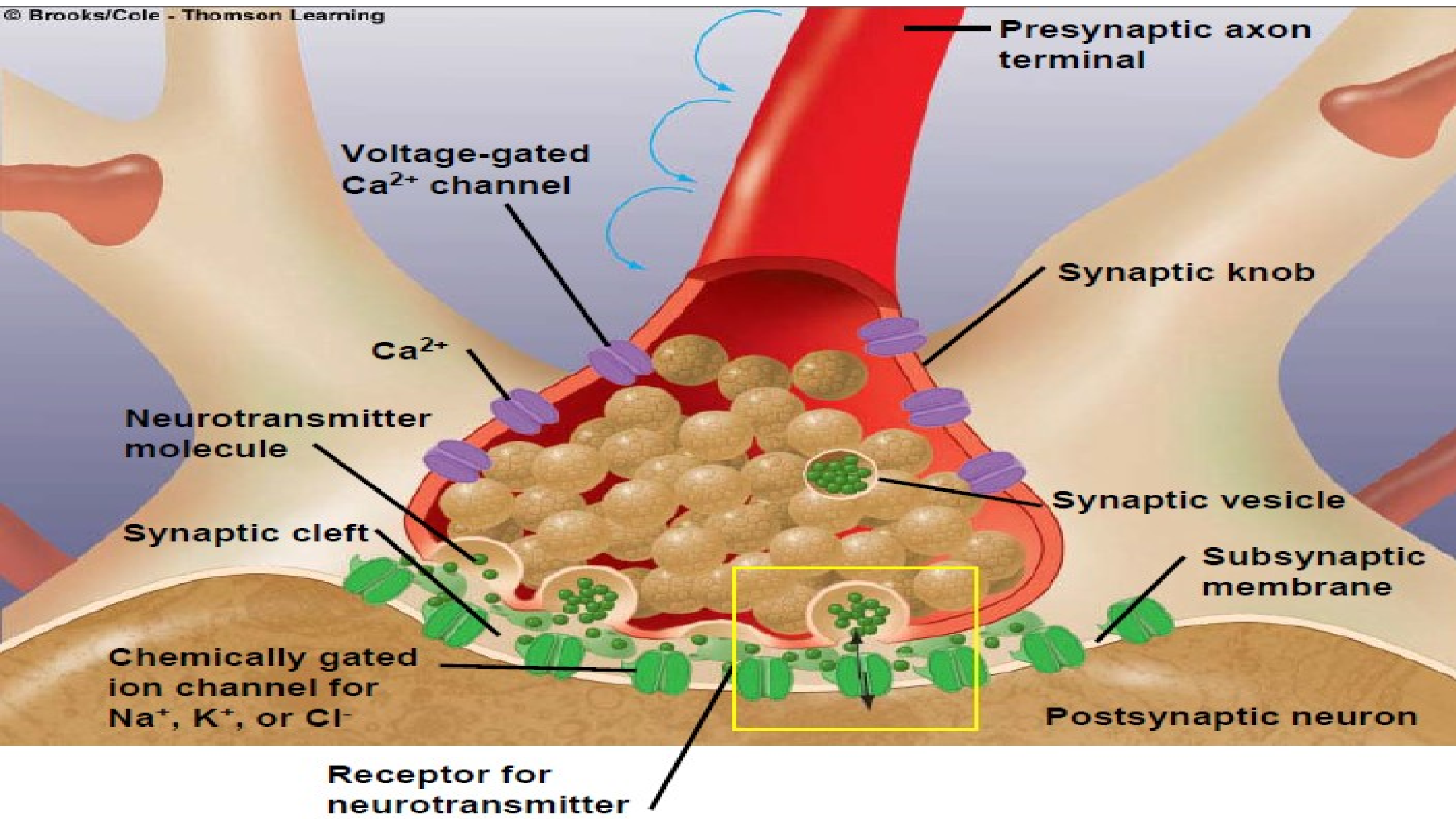
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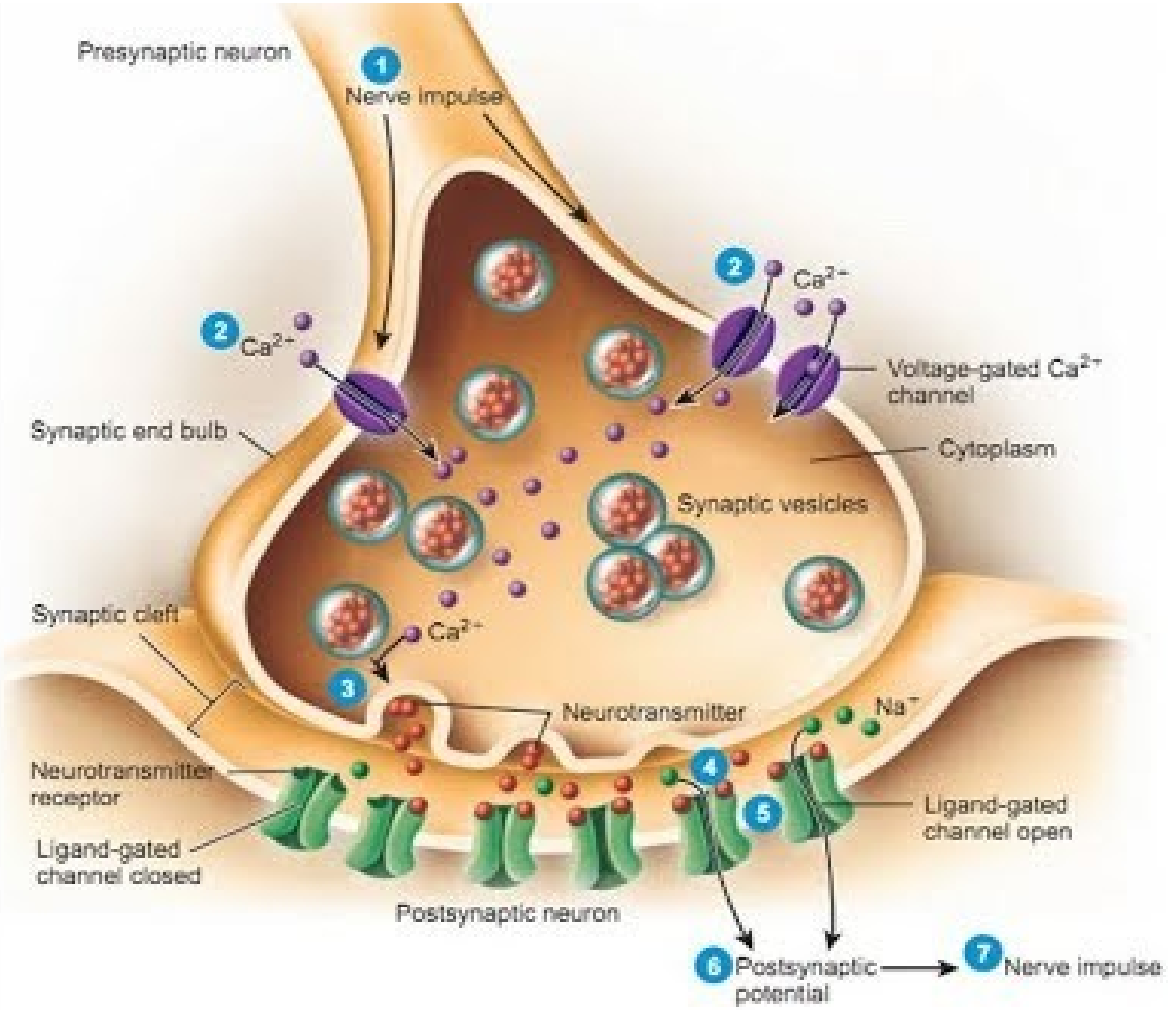
Presynaptic axon terminal
Voltage-gated Ca^{2+} channel
Synaptic knob
Ca^{2+}
Neurotransmitter molecule
Synaptic vesicle
Synaptic cleft
Subsynaptic membrane
Chemically gated ion channel for Na^+, K^+, or Cl^-
Postsynaptic neuron
Receptor for neurotransmitter

What is the trigger for neurotransmitter release?

- Pre-synaptic Calcium level

Q4: Post-synaptic potential mechanism

- The chemical transmitter (ligand) diffuses across the synaptic cleft to combine with the receptors at the postsynaptic membrane.
- This leads to change in the permeability of the postsynaptic membrane to Na+, K+ or Cl- ions, generating postsynaptic potential (PSP).



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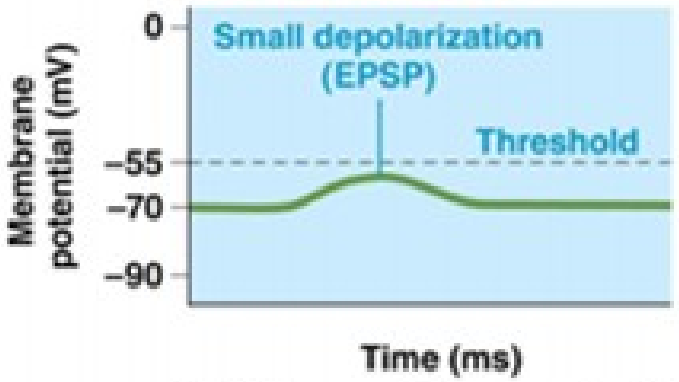
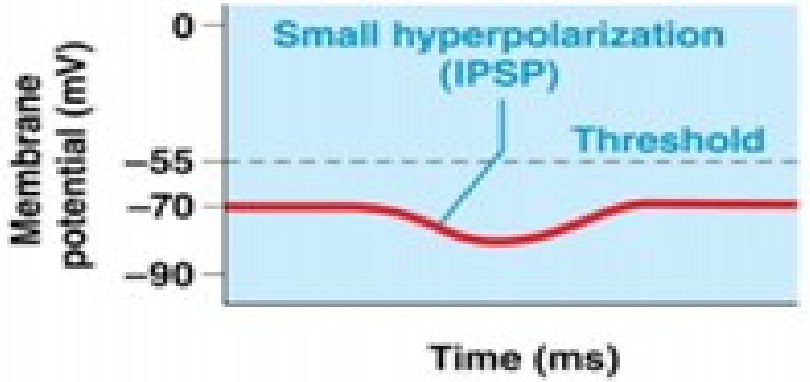
• Q5:What is postsynaptic potential?

- It is the electric activity at the synapses
- It is a **local potential**
- **Local transient change** in the membrane potential
- Can be **graded** and **summated**
- **Amplitude modulated**
- **Has 2 types: EPSP, IPSP**



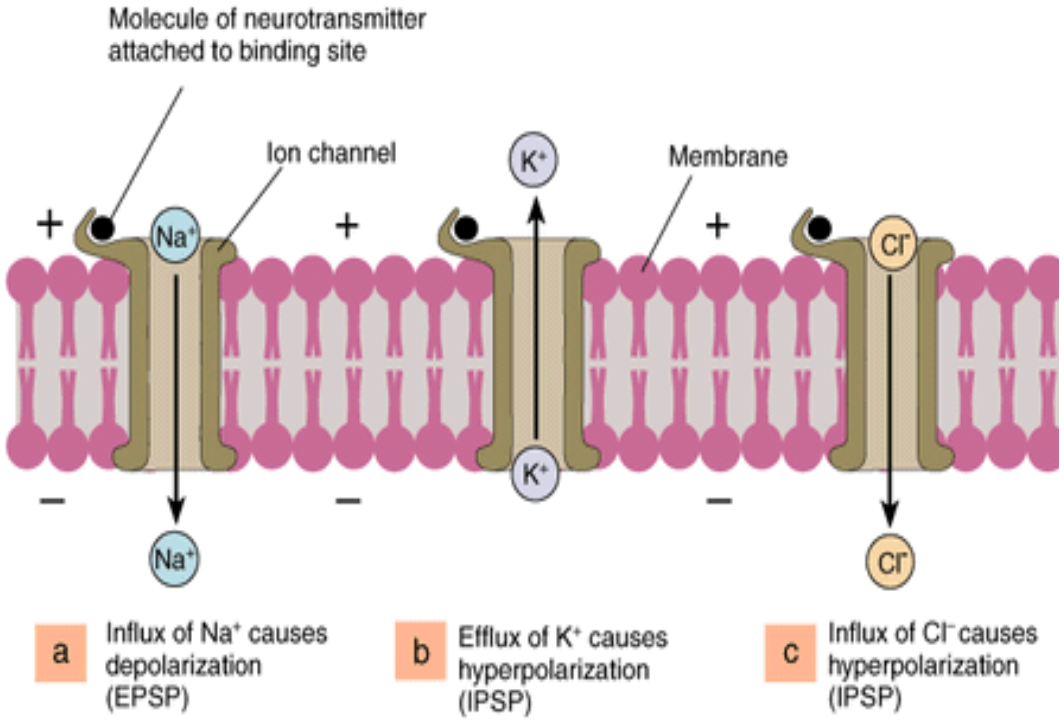
(a) The membrane potential of the postsynaptic neuron moves closer to threshold.



(b) The membrane potential of the postsynaptic neuron moves away from threshold.

6-Compare between EPSP and IPSP

IPSP	EPSP
Inhibitory postsynaptic potential	**Excitatory postsynaptic potential**
Hyperpolarize postsynaptic membrane	**Depolarize postsynaptic membrane**
Due to opening of chloride channels or potassium channels	**Due to opening of sodium channels, or closure of potassium channels**



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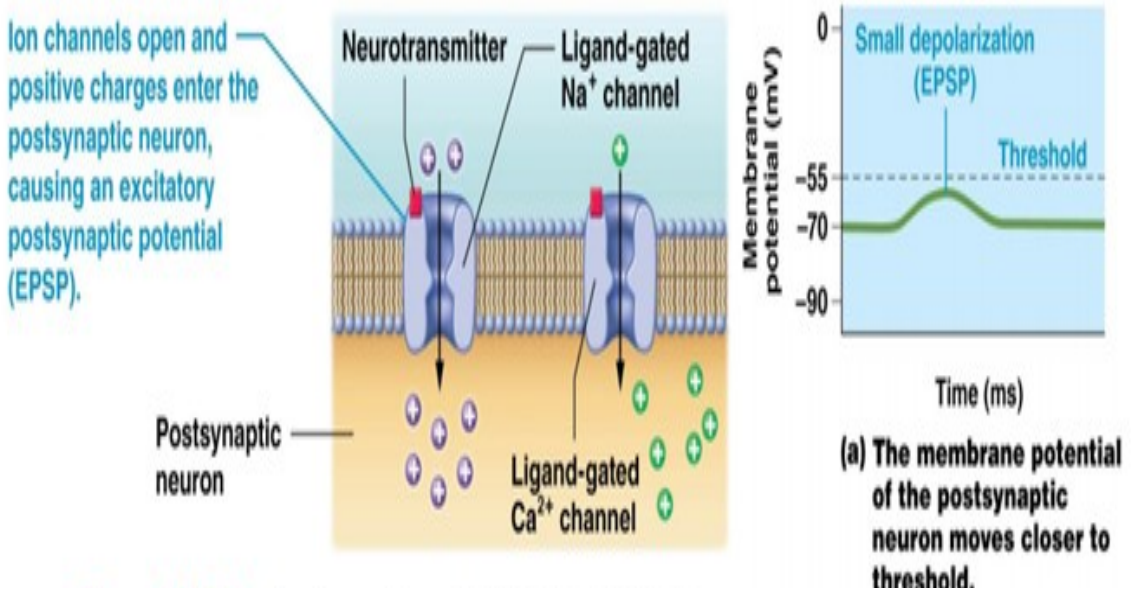
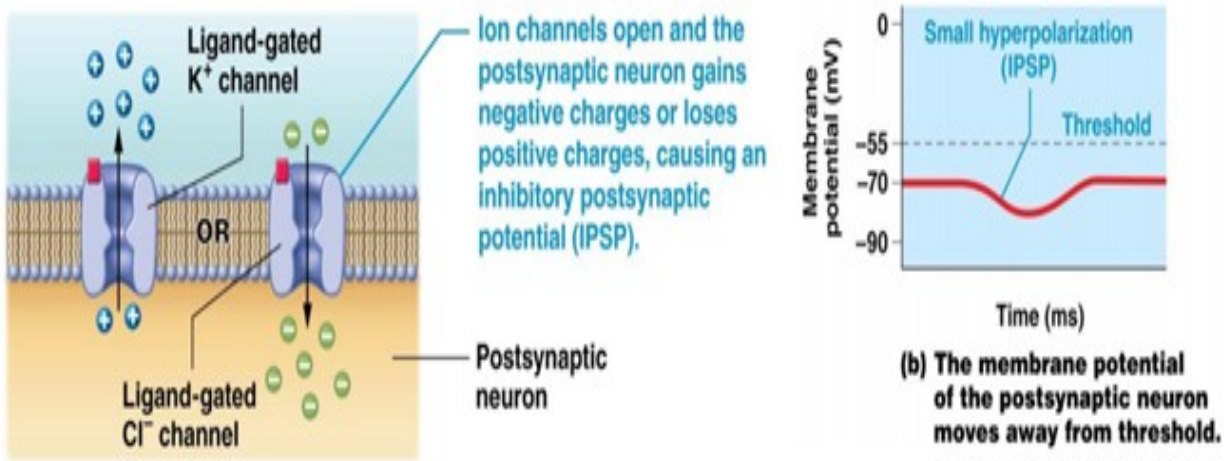
6-Compare between EPSP and IPSP

EPSP



IPSP



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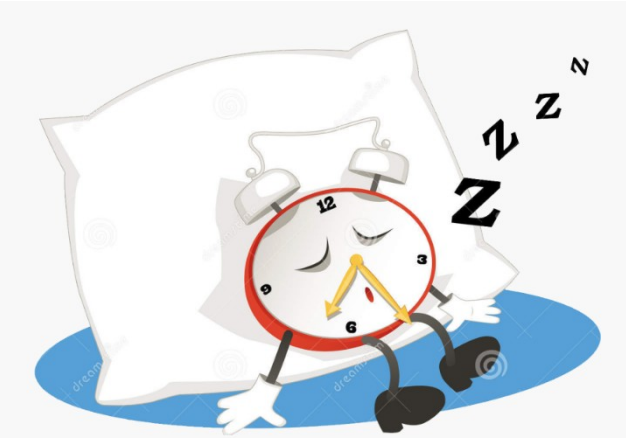
Think: **which types of synaptic potentials is working here and how?**

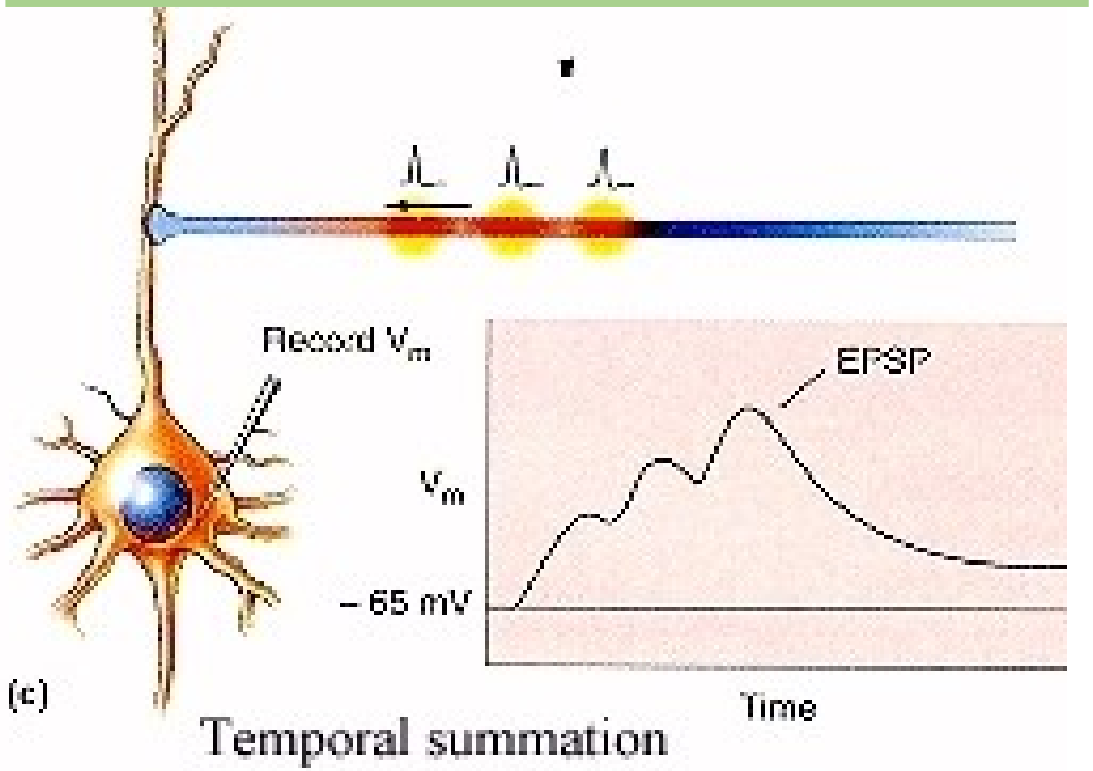


- Inhibitory post-synaptic potential

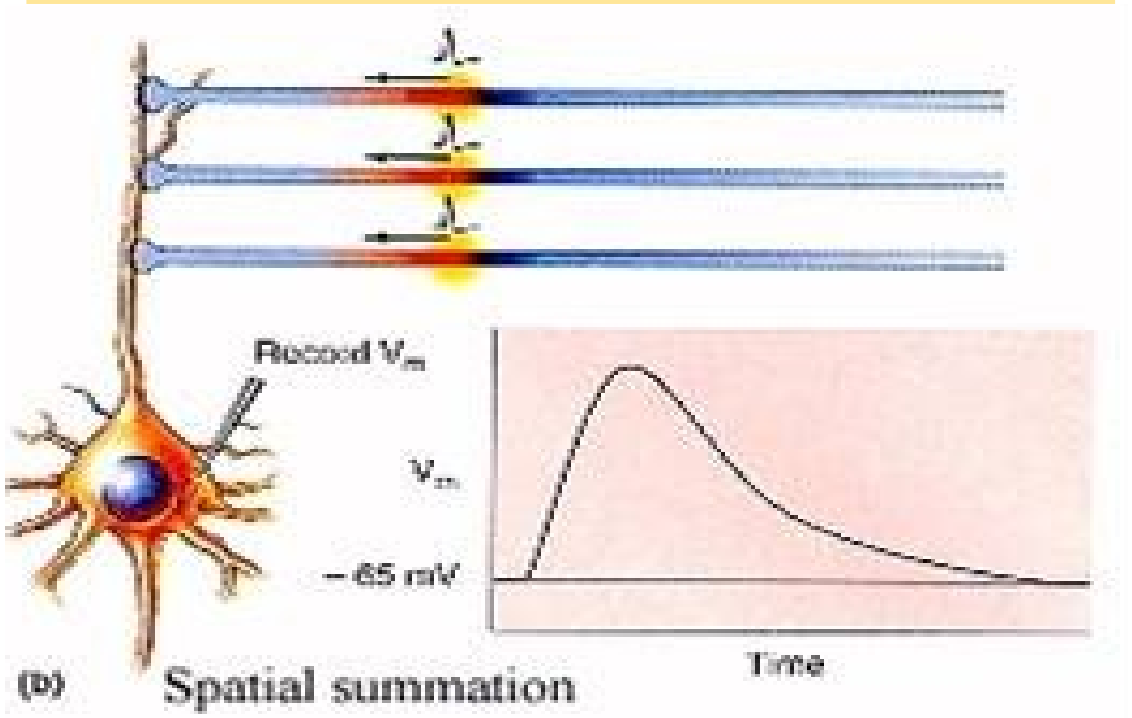
- Neurotransmitter open chloride channels or potassium channels
- Membrane potential is hyperpolarized away from threshold

Q7: What are the summation types of the Post-synaptic Potentials

- Temporal summation



- Spatial summation



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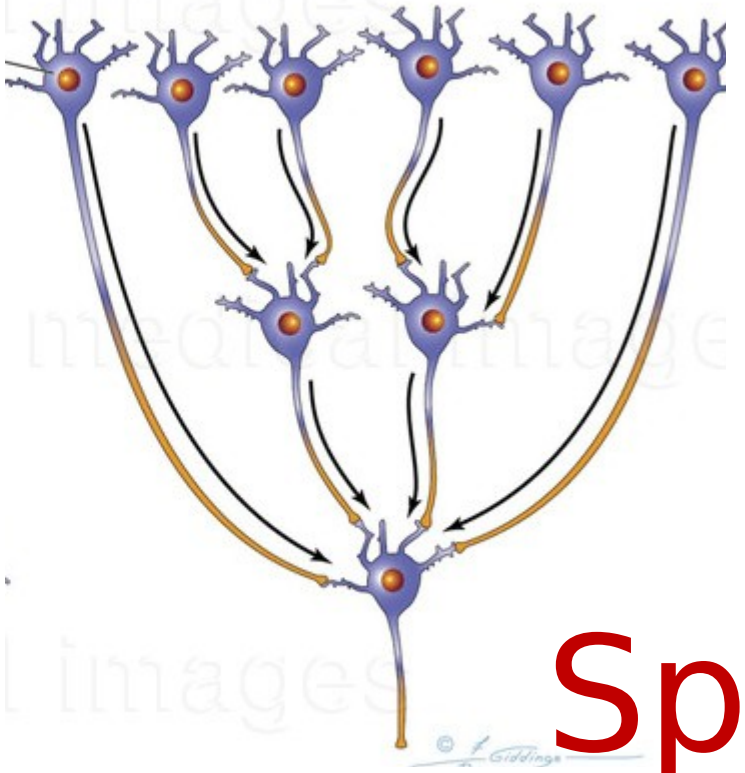
Q7: What are the summation types of the Post-synaptic Potentials

- Temporal summation
  - **One** presynaptic neuron is **repetitively stimulated (intervals< 15 msec)**
- Spatial summation
  - **Many** pre-synaptic neurons are stimulated at the **same time {simultaneously}** and ***converge on the same postsynaptic*** neuron

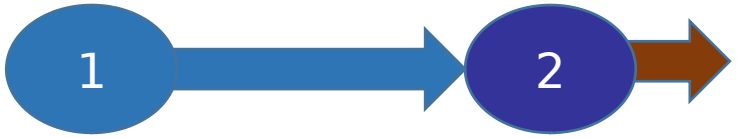
Choose: Do these pictures represent (temporal or spatial summation)



Spatial summation

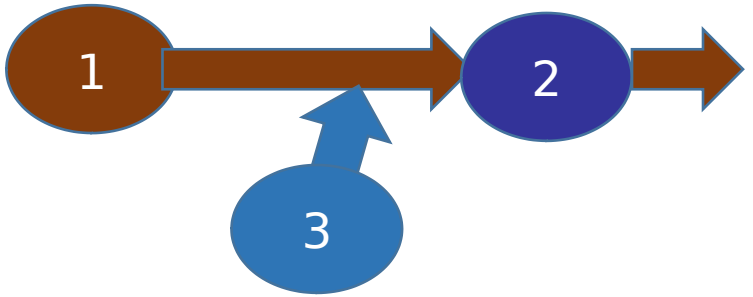
Q8:Types of synaptic inhibition

Post-synaptic inhibition



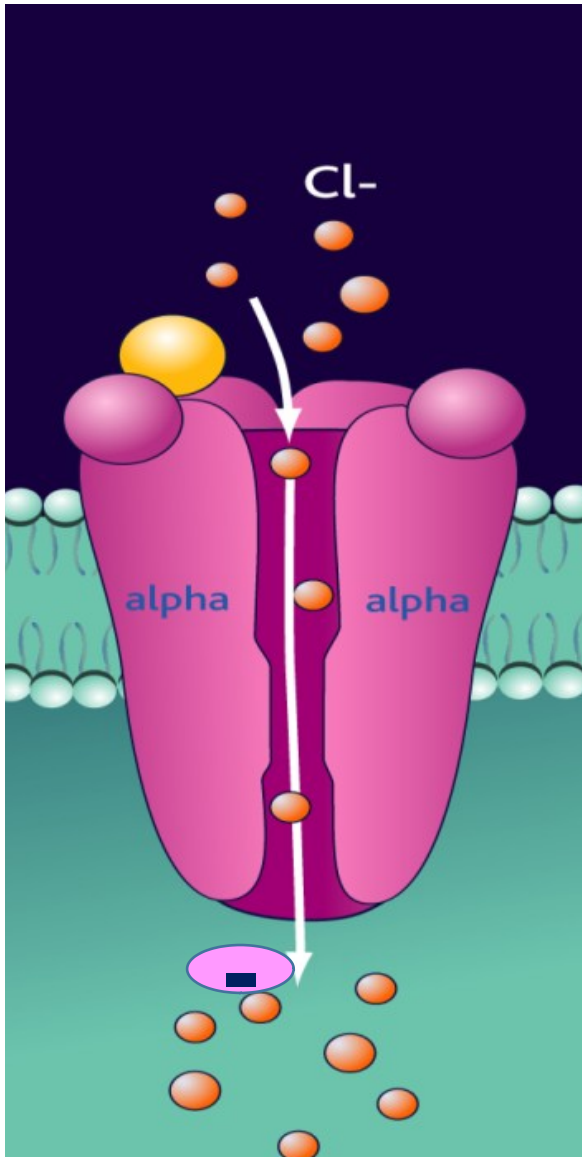
- **Pre-synaptic neuron** release **inhibitory** neurotransmitter **Glycine or GABA** to open chloride channels on the post-synaptic membrane generating IPSP

Pre-synaptic inhibition

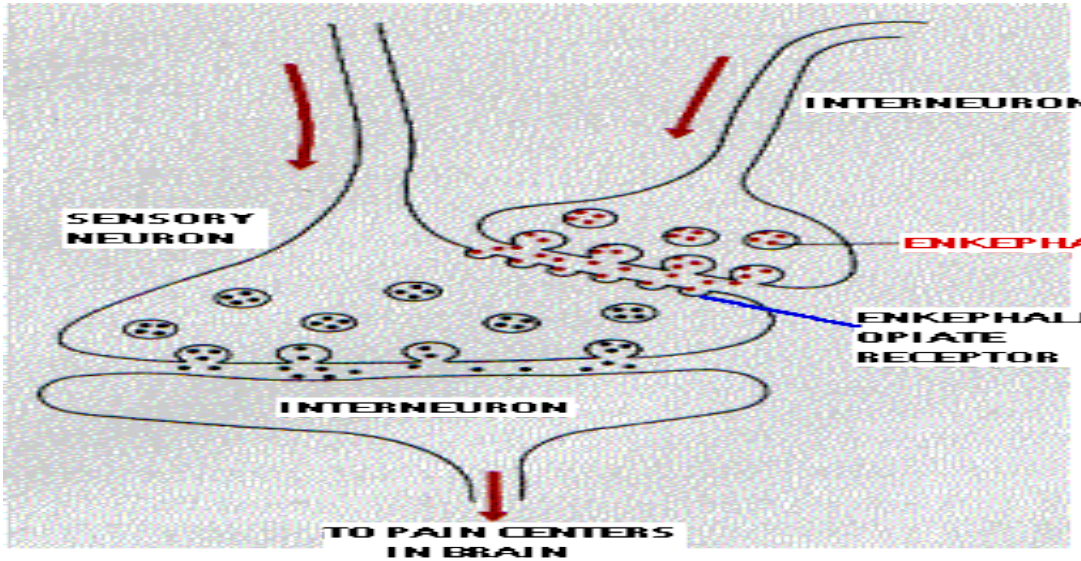


1-An inhibitory neuron releases **enkephalin** and terminate on **excitatory pre-synaptic neuron**
2- Chloride channels are opened on pre-synaptic membrane and decreases calcium influx in pre-synaptic terminal, decrease neurotransmitter release.

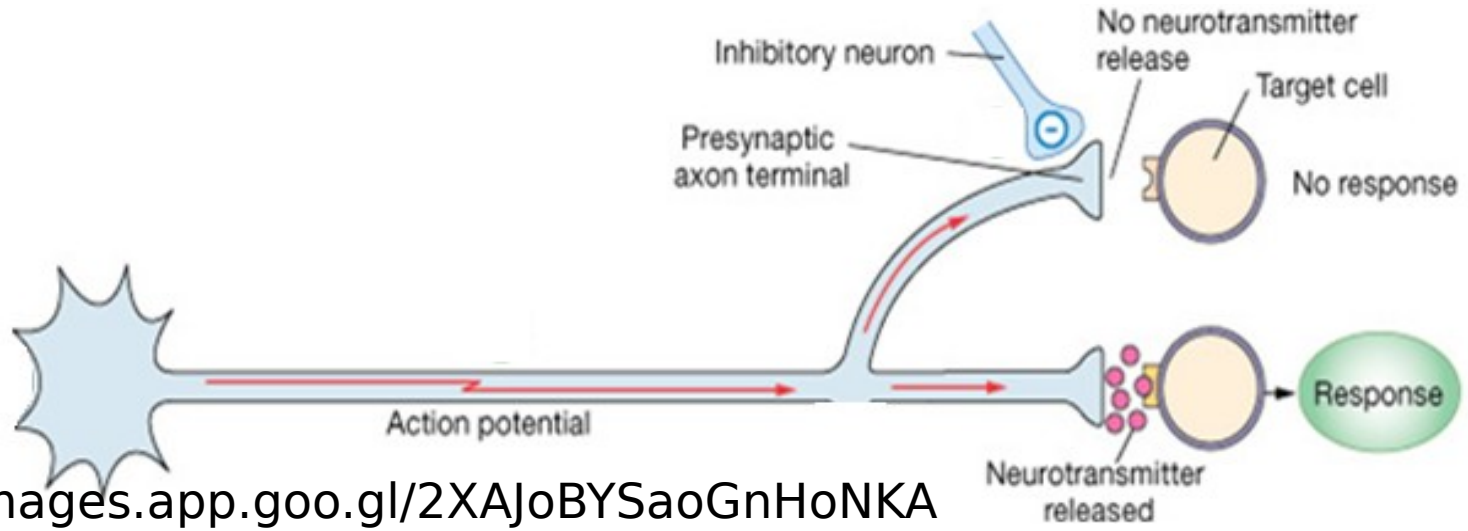
Post-synaptic inhibition



Pre-synaptic inhibition



pre-synaptic inhibition of SGR present in the posterior horn in pain control system.



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- In pre-synaptic inhibition, the neuron that releases inhibitory neurotransmitter relays on ----------

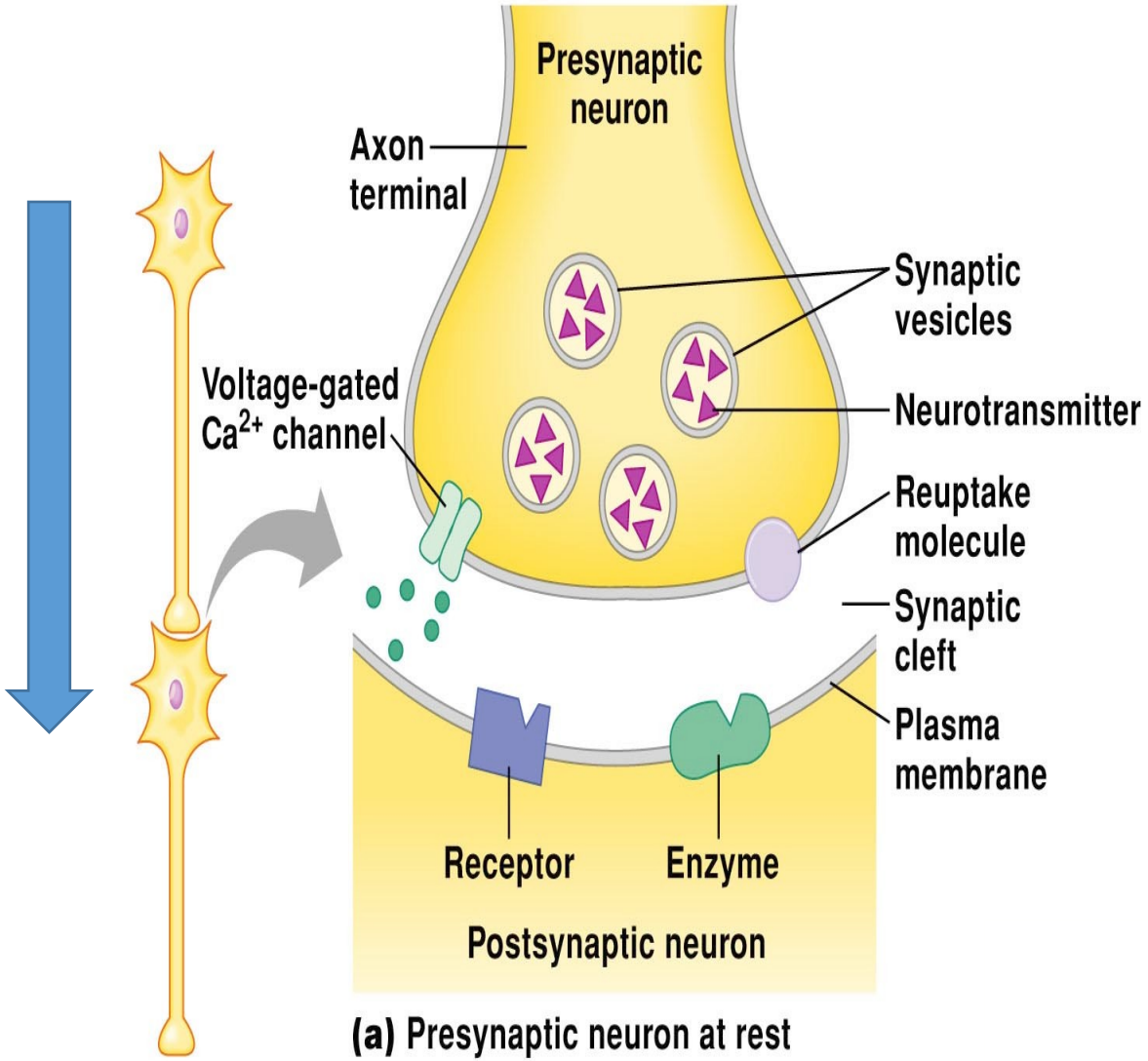
On the pre-synaptic terminal

- In post-synaptic inhibition the neurotransmitter is not released from the pre-synaptic terminal (true or false)

False

Q9- List Properties of synaptic transmission

- **1-Forward Conduction (unidirectional):**



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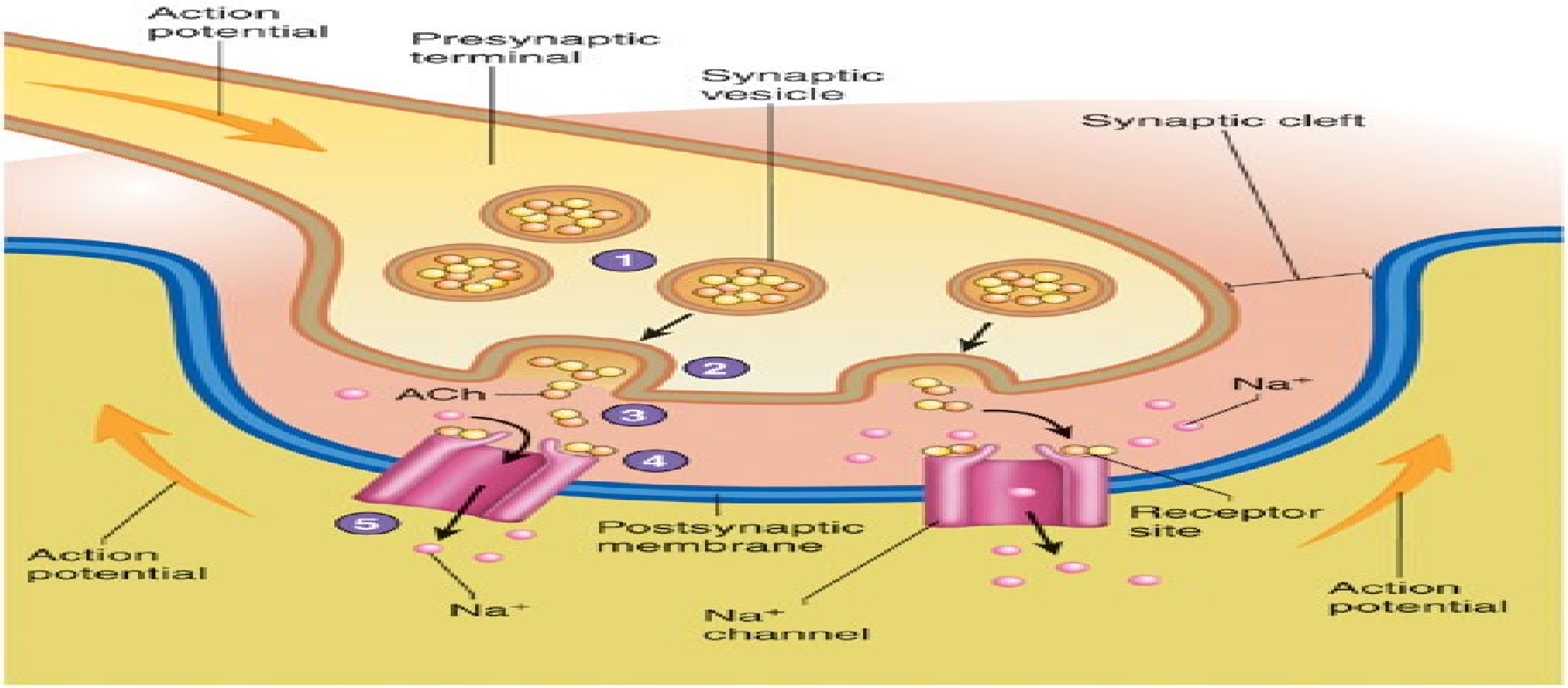
2-Synaptic Delay:



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List Properties of synaptic transmission

3- Synaptic fatigue

4-Summation of post-synaptic potentials: Temporal or spatial

5-Synaptic plasticity :

Change in the synaptic strength of transmission **on the basis of past experience**.

Could you explain how the people living in this house sleep, although they live near by the noisy train tracks?

Synaptic plasticity

- Change in the synaptic strength of transmission **on the basis of past experience**.
- In this case they are habituated (decrease in synapse response to train noise)

List Properties of synaptic transmission

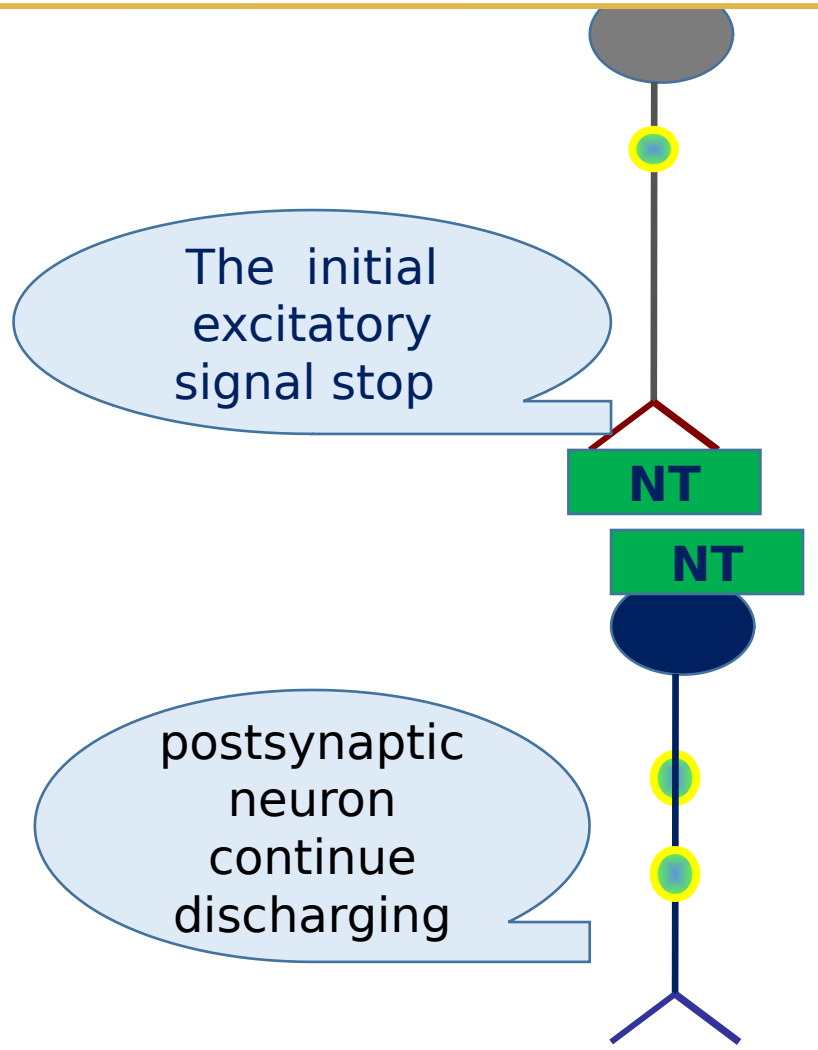
- **6- Synaptic after discharge:**

- *Def:* postsynaptic neuron continue discharging after the stoppage of the initial excitatory signal
- *Mechanism:*

- long acting neurotransmitter
- delayed inactivation of the excitatory neurotransmitter

❑ *mportance:*

- Prolong of signals in neuronal pools.



7- factors affecting synaptic transmission

	Increase synaptic transmission	Decrease synaptic transmission
Blood PH	**alkalosis**	**acidosis**
Oxygen level		**hypoxia**
Drugs	**Theophylline, caffeine**	**Anaesthetic drugs**
	Strychnine, tetanus toxin block glycine action	**Barbiturates facilitates GABA action**
Glycine and GABA are inhibitory neurotransmitters		

- **Case scenario**
  - 7 years old boy was injured but the wound was infected, he suffered from severe neck spasm. The doctor at the emergency ward diagnosed the case as tetanus poisoning, he injected the boy with barbiturates.

Case scenario

- The wound is infected by bacteria that releases tetanus toxin
- Tetanus toxin inhibit the release of GABA the inhibitory neurotransmitter leading to spastic paralysis
- GABA opens chloride channels and form IPSP
- Barbiturates benzodiazepines facilitate GABA action
- benzodiazepines provide sedation, relax the muscles and relieve pain

Summary

- Synapse is the junction between 2 neurons
- Chemical synapses are most common in CNS
- Opening of voltage gated calcium channels in the pre-synaptic knob and increase calcium level leads to exocytosis of neurotransmitter vesicles
- Neurotransmitter binds to postsynaptic receptors, If it **opens sodium** channels, or **close potassium** channels, **EPSP** is generated and if it **opens chloride** or **potassium channels**, **IPSP** is generated
- Postsynaptic potential is a local potential, can be graded and summated
- Temporal summation: repeated stimulation of one pre-synaptic neuron
- Spatial summation: Stimulation of many pre-synaptic neurons at the same time
- Post-synaptic inhibition: inhibitory transmitter produces IPSP
- Pre-synaptic inhibition: the inhibitory interneuron decreases neurotransmitter release from the pre-synaptic neuron.
- Impulses are transmitted from the presynaptic neuron to the postsynaptic neuron in one way direction with a delay 0.5 m sec
- Synaptic after discharge, synaptic plasticity

SUGGESTED TEXTBOOKS

1. Ganong review of medical physiology, 26 th edition,

   chapter 6. Synaptic and junctional transmission, P297

2. Fox human physiology , 14th edition, chapter 7